Landscape and Urban Planning 180 (2018) 103–113

Contents lists available at ScienceDirect

Landscape and Urban Planning

journal homepage: www.elsevier.com/locate/landurbplan

Research Paper

Plant species or flower colour diversity? Identifying the drivers of public and invertebrate response to designed annual meadows

Helen Hoyle[a,*], Briony Norton[b], Nigel Dunnett[c], J. Paul Richards[b], Jean M. Russell[d], Philip Warren[b]

[a] Department of Landscape, University of Sheffield, Centre for Sustainable Planning and Environments, UWE, Bristol, United Kingdom
[b] Department of Animal and Plant Sciences, University of Sheffield, United Kingdom
[c] Department of Landscape, University of Sheffield, United Kingdom
[d] Department of Corporate Information and Computing Services, University of Sheffield, United Kingdom

ARTICLE INFO

Keywords:
Urban meadows
Green infrastructure
Flower colour diversity
Plant species diversity
Human aesthetic response
Invertebrate response

ABSTRACT

There is increasing evidence of the benefits of introducing urban meadows as an alternative to amenity mown grass in public greenspaces, both for biodiversity, and human wellbeing. Developing a better understanding of the meadow characteristics driving human and wildlife response is therefore critical. We addressed this by assessing public and invertebrate response to eight different annual meadow mixes defined by two levels of plant species diversity and two levels of colour diversity, sown in an urban park in Luton, UK, in April 2015. On-site questionnaires with the visiting public were conducted in July, August and September 2015. Invertebrate responses were assessed via contemporaneous visual surveys and one sweep net survey (August 2015). Flower colour diversity had effects on human aesthetic response and the response of pollinators such as bumblebees and hoverflies. Plant species diversity, however, was not a driver of human response with evidence that people used colour diversity as a cue to assessing species diversity. Plant species diversity did affect some invertebrates, with higher abundances of certain taxa in low species diversity meadows. Our findings indicate that if the priority for sown meadows is to maximise human aesthetic enjoyment and the abundance and diversity of observable invertebrates, particularly pollinators, managers of urban green infrastructure should prioritise high flower colour diversity mixes over those of high plant species diversity. Incorporating late-flowering non-native species such as *Coreopsis tinctoria* (plains coreopsis) can prolong the attractiveness of the meadows for people and availability of resources for pollinators and would therefore be beneficial.

1. Introduction

Whilst there is increasing recognition of the importance of urban green infrastructure (GI) for biodiversity (Rudd, Vala, & Schaefer, 2002; Williams, Lundholm, & MacIvor, 2014) and human wellbeing (Lovell, 2016; White, Alcock, Wheeler, & Depledge, 2013) and the links between them (Carrus et al., 2015; Dallimer et al., 2012; Fuller, Irvine, Devine-Wright, Warren, & Gaston, 2007), there is still a greater need to go beyond a simple classification that regards all GI as broadly equivalent or homogenous (Clark et al., 2014; Velarde, Fry, & Tveit, 2007). Some studies have attempted to tease apart the elements of urban GI that contribute to the benefits for biodiversity (Rudd, Vala, & Schaefer, 2002; Williams et al., 2014) and people (Hoyle, Hitchmough, & Jorgensen, 2017a; Qiu, Lindberg, & Nielsen, 2013; Vandermeulen, Verspecht, Vermeire, Van Huylenbroeck, & Gellynck, 2011). Others have focused on the pathways between 'nature' and wellbeing (Hartig, Mitchell, de Vries, & Frumkin, 2014) or on the costs: financial (Hanley & Barbier, 2009; Ozdemiroglu & Hails, 2016; Vandermeulen et al., 2011) and otherwise (Hoyle et al., 2017) of realising the benefits. GI can improve urban systems, as evidenced above, but there is real potential for maximising its benefits by appropriate attention to its composition and management (Clark et al., 2014; Hoyle et al., 2017a).

Unpicking the complexities of human and invertebrate responses to urban GI is particularly relevant in the case of mown amenity grassland; a major component of urban environments in temperate regions (Irvine et al., 2009); Kazmierczak, Armitage, & James, 2010). In the UK, approximately two-thirds of urban GI is managed as closely mown amenity grass used primarily for recreation (Forestry Commission, 2006).

* Corresponding author at: Department of Architecture and the Built Environment, Frenchay Campus, Coldharbour Lane, Bristol BS16 1QY, United Kingdom.
E-mail addresses: Helen.hoyle@uwe.ac.uk (H. Hoyle), Briony.norton@sheffield.ac.uk (B. Norton), Nigel.dunnett@sheffield.ac.uk (N. Dunnett), paul.richards@sheffield.ac.uk (J.P. Richards), j.russell@sheffield.ac.uk (J.M. Russell), p.warren@sheffield.ac.uk (P. Warren).

https://doi.org/10.1016/j.landurbplan.2018.08.017
Received 28 December 2017; Received in revised form 13 August 2018; Accepted 22 August 2018

One increasingly popular diversification of urban grassland is the introduction of "urban meadows" – more biodiverse sown grasses and forbs, subject to limited seasonal cutting, and producing more structurally complex and florally diverse habitats. Urban meadows are considered to provide a nature-based solution to managing green infrastructure (GI) by harnessing ecological processes to deliver cost effective environmental and social benefits (European Commission Research, 2016). Such approaches are attractive to planners and policy makers prioritising the physical and psychological well-being of growing urban populations (e.g. Glasgow and Clyde Valley Green Network Partnership, 2016; Greater London Authority, 2015) and the resilience of ecosystem services in the face of population growth and climate change (e.g. EU Biodiversity Strategy, 2020). "Urban meadows" may be introduced using perennial seed mixes which include grasses and flower species which persist and flower over multiple years, or annual mixes, which comprise flower species which flower once, but may persist by self-seeding (Hoyle, 2016).

There is a growing evidence base for the benefits for people and wildlife of introducing urban meadows as an alternative to closely mown amenity grassland (Baldock et al., 2015; Buri, Humbert, & Arlettaz, 2014; Garbuzov & Ratnieks, 2014; Garbuzov, Fensome, & Ratnieks, 2015; Harmon-Threatt & Hendrix, 2015; Southon, Jorgensen, Dunnett, Hoyle, & Evans, 2017). Such meadows have the potential to reduce the frequency of mowing required, increasing habitat provision for invertebrates (Blackmore & Goulson, 2014; Buri et al., 2014), nectar and pollen for invertebrates (Baldock et al., 2015; Garbuzov & Ratnieks, 2014; Harmon-Threatt & Hendrix, 2015) and aesthetic value for site users (Garbuzov et al., 2015; Graves, Pearson, & Turner, 2017; Southon et al., 2017). The impacts of sown urban meadows on birds and small mammals are yet to be investigated, but results of research focusing on mowing patterns and changes to less structurally complex meadows and grasslands in agricultural areas would indicate a positive effect on abundance and diversity of species (Frawley & Best, 1991; Garratt, Minderman, & Whittingham, 2012).

This existing evidence base for the benefits of urban meadows focuses mainly on either the public or pollinator response to meadows. Most research addressing human reactions to meadows has emphasised the role of plant species diversity (e.g. Akbar, Hale, & Headley, 2003; Lindemann-Matthies & Bose, 2007; Lindemann-Matthies, Junge, & Matthies, 2010; Southon et al., 2017; Strumse, 1996) and structure (Lindemann-Matthies & Bose, 2007; Southon et al., 2017), providing evidence for a positive relationship between plant species richness or diversity and public aesthetic appreciation (Lindemann-Matthies, Junge, & Matthies, 2010; Southon et al., 2017) although recent findings (Graves, Pearson, & Turner, 2017) indicate that species richness alone does not predict the cultural ecosystem service value of wildflower meadows. This latter study showed that public aesthetic preference increased with species evenness, flower colour diversity and the abundance of flowers, but was unrelated to species richness (Graves et al., 2017). Other public preference research has highlighted human reaction specifically to flowers or flower colour (Haviland-Jones, Hale, Wilson, & McGuire, 2005; Hoyle et al., 2017b; Ogunseitan, 2005; Todorova, Asakawa, & Aikoh, 2004). Todorova et al. (2004) found participants selected low, ordered, brightly-coloured flowers over tall or subtly coloured flowers, bare soil, grass or hedge as possible ground cover underneath street trees. Hoyle et al. (2017b) identified that in UK woodland, shrub and herbaceous planting experienced first-hand, people found flower cover of 27% or more to be significantly more attractive than a lower percentage flower cover.

Research in Italy (Carrus et al., 2015) highlighted the positive effect of actual biodiversity on well-being in both urban and peri-urban environments. In urban areas biodiverse urban parks were perceived as more restorative than less biodiverse urban squares. In peri-urban environments, biodiverse natural protected areas were perceived as more restorative than less biodiverse pinewood forest plantations. An important consideration in understanding human responses to biodiversity enhancements such as urban meadows is understanding the resolution at which people perceive biodiversity. Qiu et al. (2013) found that people could recognise broad habitat types, and Hoyle, Hitchmough and Jorgensen (2017a) found that people recognised the difference between three broad levels of native biodiversity in urban planting. Nevertheless, it seems most people's biodiversity recognition skills are poor at the level of individual plant, invertebrate and bird species (Dallimer et al., 2012; Fischer, Bednar-Friedl, Langers, Dobrovodska, Geamana, Skogen, & Dumortier, 2011; Fuller et al., 2007).

The factors potentially responsible for attracting pollinators and other insects to plants include flower shape, size, scent or colour, pollen and nectar availability (Baldock et al., 2015); Goulson & Osborne, 2009; Haslett, 1989; Kim, Gilet, & Bush, 2011; Pellmyr, 2002). Studies addressing pollinator visitation to meadows have considered pollinator visitation within networks involving specific plant species (Baldock et al., 2015), the timing of pollinator visits (Baldock et al., 2011), the role of plant species abundance (Winfree, Dushoff, Williams, & Kremen, 2014) and plant traits (Chamberlain et al., 2014)including colour (Campbell, Bischoff, Lord, & Robertson, 2012) although the effect of colour is not always important (Garbuzov & Ratnieks, 2014).

Whilst existing studies suggest that colourful, flowering urban meadows have benefits for people or pollinators, there is, to date, a lack of integrative research investigating the role of flower colour and abundance, plant species diversity, and their relative importance as drivers of both public and invertebrate response to designed urban meadows. Here we tested public and invertebrate response to eight designed annual meadow mixes in an urban park environment, where each mix had a combination of two levels of species and two levels of colour diversity. Specifically, we asked whether plant species diversity, flower colour diversity, or flower abundance are important determinants of aesthetic response and restorative effect for people and for the abundance and diversity of invertebrates. In addition, we examined how well members of the public observe and recognise plant and invertebrate biodiversity.

2. Methods

2.1. Experimental meadow design and sowing beds

A total of 19 forb species were used to design 8 different annual meadow mixes. These represented two levels of species diversity (low: 4–7 spp., high: 9–17 spp.) and two levels of colour diversity Fig. 1, Table 1). Mixes included: 2 × low species, low colour diversity A (1) & A (2), 2 × high species, low colour diversity B (1) & B (2), 2 × low species, high colour diversity C (1) & C (2) and 2 × high species, high colour diversity D (1) & D (2). Having two different species mixes for each diversity/colour combination was intended to provide some insurance against strong 'species effects' where the effect of a treatment was not separable from the effect of the particular species involved. The full species mixes for each treatment combination are given Table 1: both native and non-native species were included, and the species palette reflected those incorporated into commercially available annual meadow mixes. Some non-native species such as *Coreopsis tinctoria* (plains coreopsis) were included to extend the flowering season beyond that of native species, thus extending both the visual impact of the meadows for human visitors, and the availability of sources of nectar and pollen for invertebrates (Salisbury et al., 2015). The experiment was located on a former mini-golf site within an enclosed area of Wardown Park, Luton, UK, a well-visited urban park. Each meadow mix was randomly allocated to three of 24 pre-prepared plots of 6 × 10 (60 m^2) on a uniformly chalky, well-drained site within the park. To prepare the site, amenity mown grass was removed by spraying with glyphosate-based herbicide in March 2015, with strips of mown grass 5 m wide retained between plots. Plots were then twice rotovated in mid-April 2015 to achieve a fine sowing tilth. Seed was mixed with

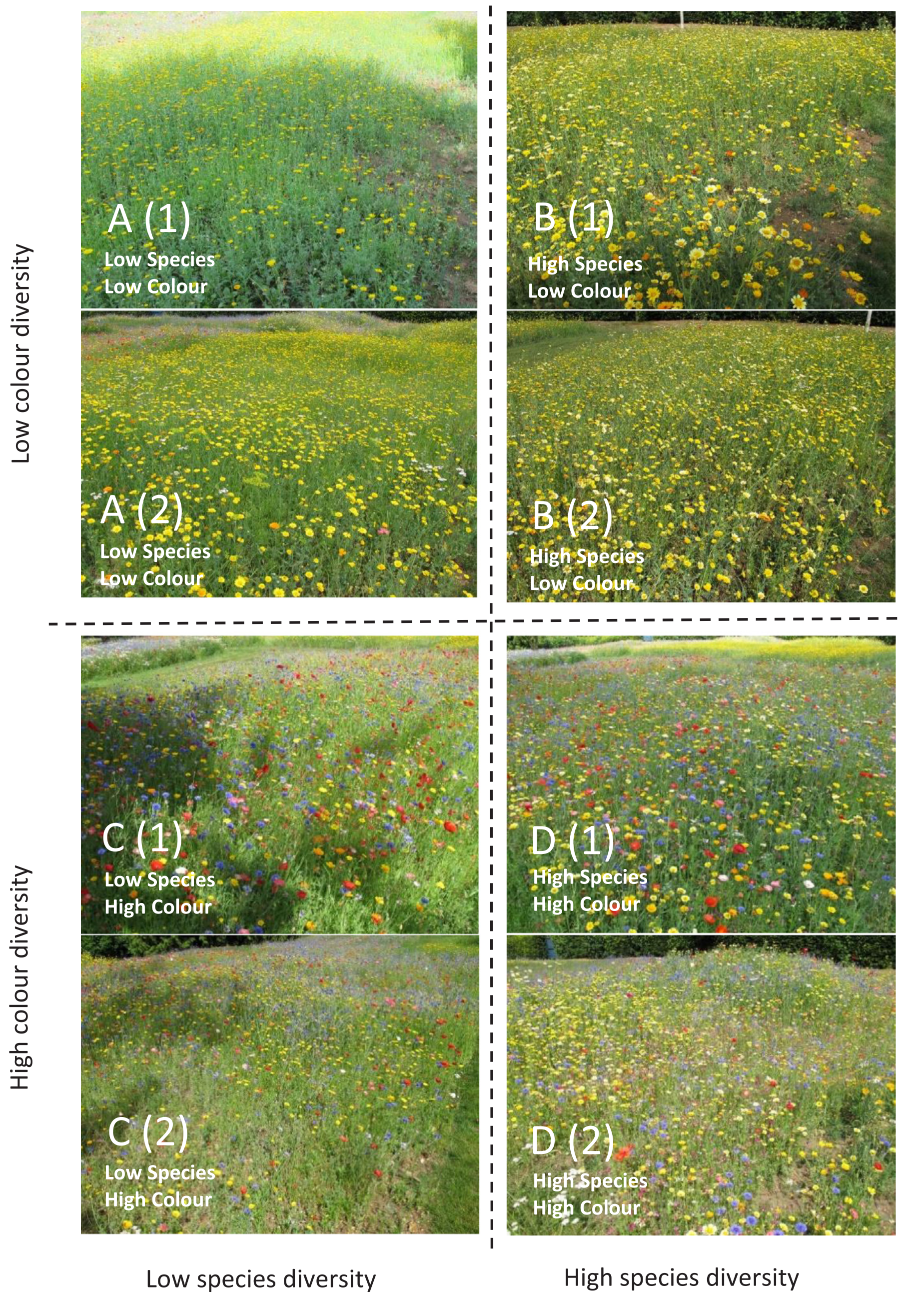

Fig. 1. Experimental design showing mixes (A-D) as combinations of low and high species and colour diversity (Phase 1: July 2015).

sand and hand-sown at a rate of 3 g/m^2 at the end of April 2015.

2.2. Questionnaires with the visiting public

An on-site self-guided questionnaire (after Hoyle et al., 2017a; 2017b) was used to assess human aesthetic reaction to the meadow plots, restorative effect and perceived biodiversity. Most items in the questionnaire took the form of attitudinal statements, using a five-point Likert scale from +2 (agree strongly) to −2 (disagree strongly), following established methodology (e.g. Ives & Kendal, 2013) Table 2). Three questions focusing on perceived biodiversity value of the meadows involved participants answering within the categories: ‘many’, ‘some’ ‘few’ or ‘none’. A direct rating approach was used to assess restorative effect, with single items applied to measure each of the four components of attention restoration theory (ART, Kaplan, 1995), (see Table 2. This followed Herzog, Maguire and Nebel’s (2003) approach, adapted by Hoyle et al. (2017, 2017a, 2017b) to address human reactions to a range of natural planted environments. A section focusing on the respondents’ demographic characteristics was included. Signage was placed on a notice board at the entrance to the meadows enclosure to indicate the days when the meadows would be ‘open’ to the public, when the lead researcher was present. On these occasions all visitors to the meadows enclosure and the area of the park surrounding the experimental site were approached as potential participants. Once visitors had agreed to take part in the research they were randomly allocated to one of the eight meadow mixes, and asked to walk around the selected plot, responding to that plot alone. Three phases of questionnaire survey were carried out: in July (n = 38); August (n = 67); and September (n = 44) (several days within each phase, incorporating both weekdays and weekends). These corresponded with the timings of the three flowering and three visual invertebrate surveys. The intention was to capture the public, and invertebrate response across the flowering season (2015).

Table 1
Seed mixes: percentage species by weight.

Species name	Common name	Mix A (1) Low spec Low col	Mix B (1) Hi spec Low col	Mix C (1) Low spec Hi col	Mix D (1) Hi spec Hi col	Mix A (2) Low spec Low col	Mix B (2) Hi spec Low col	Mix C (2) Low spec Hi col	Mix D (2) Hi spec Hi col
Anethum graveolens	Dill	–	–	–	–	15	15	–	–
Ammi majus	Bishop's flower	–	–	–	7	–	–	–	7
Atriplex hortensis 'rubra'	Red orache	–	–	–	–	–	–	4	4
Calendula officinalis 'Orange King'	Pot marigold	25	10	20	5	20	10	21	5
Centaurea cyanus	Cornflower	–	–	10	10	–	–	10	8
Glebionis coronaria (Chrysanthemum coronarium)	Garland chrysanthemum	–	10	–	5	–	5	–	5
Glebionis coronaria (Chrysanthemum segetum) 'Mixture'	Corn marigold	25	10	20	5	20	10	20	5
Coreopsis tinctoria 'Standard Tall Mixture'	Plains coreopsis (tall)	35	20	25	12	30	25	25	12
Coreopsis tinctoria 'Standard Dwarf Mixture'	Plains coreopsis (dwarf)	–	10	–	–	–	–	–	–
Cosmos sulphureus	Cosmos	–	15	–	10	–	10	–	5
Cosmos bipinnatus 'Albatross'	Cosmos	–	–	–	–	–	–	–	10
Dimorphotheca sinuata 'Mixed hybrids'	African daisy	–	10	–	8	–	10	–	8
Eschscholtzia californica	Californian poppy	15	10	15	8	15	10	15	6
Gypsophila elegans 'Covent Garden'	Baby's breath	–	–	–	5	–	–	–	5
Layia elegans	Lady tips	–	5	–	5	–	5	–	5
Linaria maroccana 'Fairy Bouquet'	Toadflax	–	–	–	5	–	–	–	3
Linum grandiflorum 'rubrum'	Red flax	–	–	–	8	–	–	–	5
Papavar rhoeas 'Shirley Mixture'	Shirley poppy	–	–	10	2	–	–	10	2
Silene armeria 'Electra'	Catchfly	–	–	–	5	–	–	–	5
Total number of species		4	9	6	15	5	9	7	17

Table 2
On-site questionnaire: Individual attitudinal statements and questions used to address participants' perceptions of the (a) aesthetic qualities, (b) restorative effect (c) biodiversity value of the meadows.

Research theme	Questionnaire Measures (Individual attitudinal statements & questions)
Aesthetic qualities	The planting along this walk is interesting The planting on this walk is attractive The planting on this walk looks natural The planting on this walk looks cared for The planting on this walk looks designed The planting on this walk looks tidy The planting on this walk looks familiar to me The planting on this walk is colourful The combination of colours is attractive in this planting How structurally complex would you describe this planting?
Restorative effect	I feel comfortable on this walk (compatability) This walk allows me to escape more mundane routines and work (being away) I feel relaxed on this walk (extent) This walk reveals a special unique place (fascination)
Perceived biodiversity value	How many different plant species do you think there are here? How many native UK plant species do you think are in this planting? The planting along this walk appears good for butterflies, bees and other insects How many species of native UK insects (flies, butterflies, bees) do you think this planting will support?

2.3. Flowering abundance surveys

Flowering abundance was estimated following an established method (Heard et al., 2007; Salisbury et al., 2015). For each plant species within a defined 10 m^2 zone of each plot an estimate of the number of flowering units (a single flower or umbel) was made in the categories: 0, 1–5, 6–20, 21–100, 101–500, 501–1000. The median value within each category for each plant species was then summed to give a total abundance for the (10 m^2) section of the plot. These estimates were made on three separate days, one in July, then August and September 2015, corresponding with the timing of the questionnaire surveys and visual invertebrate surveys.

2.4. Invertebrate surveys

Invertebrates were surveyed using two methods: firstly visually, to capture the invertebrate biodiversity observable to the visiting public and secondly by sweep sampling to get a sample of the actual invertebrates present within the upper layers of the meadow vegetation.

2.4.1. Visual surveys

Visual invertebrate surveys were done by the lead researcher (an informed non-specialist observer). Three surveys were carried out on 21st July; 11th August and 2nd September 2015, to coincide with the timing of the questionnaires and flowering abundance surveys. On each occasion, the researcher walked slowly around each plot for six minutes counting all visible invertebrates resting on flowers and vegetation. Each of the 24 plots was randomly selected and surveyed once on each occasion. Invertebrates were classified into the following categories: butterflies and moths, true flies, hoverflies, bumble bees, honeybees and other small bees (total bees), non-parasitic wasps, ants, ladybirds, other beetles, dragonflies and damselflies, spiders, snails and true bugs. These were selected as they are readily perceivable by members of the public and have sufficiently different morphology to be recognised as different from each other. The surveys were done between 10:00 and 17:00 on dry days with an ambient temperature above 16 °C.

2.4.2. Sweep surveys

One invertebrate sweep survey was performed during the flowering season. This was conducted by a researcher experienced in entomological sampling, on 17th August 2015, to coincide with the middle of the flowering season, second phase of questionnaire surveys and second visual invertebrate survey event. The sweep was taken through the middle of the plot, parallel to the long edge, using a wide (60 cm diameter × 1 m deep) white insect net in an arc of approximately 1.5 m. Specimens were killed and preserved in 70% ethanol immediately after sampling. Samples were then sorted and identified at least to order level and in some cases to lower taxonomic levels to facilitate comparison with the non-expert visual invertebrate measures. The following groups were identified and included in analysis: butterflies and moths (Lepidoptera), true flies (non-syrphid Diptera), hoverflies (Diptera: Syrphidae), bees (Hymenoptera: Apoidea), non-parasitic wasps (Hymenoptera: Vespoidea), parasitic wasps (Hymenoptera: Parasitica), other beetles (Coleoptera except Coccinellidae), ladybirds (Coleoptera: Coccinellidae), true bugs (Hemiptera), spiders (Araneae) and thrips (Thysanoptera).

3. Statistical analyses

3.1. Public response to the meadows

To assess whether plant species diversity, flower colour diversity, or flower abundance were drivers of human aesthetic response and restorative effect an initial Principal Components Analysis (PCA) with a varimax rotation was applied to all questionnaire items Table 2 to identify items which varied in a consistent pattern and loaded onto single components, each measuring a specific dimension of participants' perceptions (after Kendal, Williams, & Williams, 2012; Hoyle et al., 2017, 2017a, 2017b). Parallel analysis (Watkins, 2005) was used to extract meaningful components. Two multi-factor ANOVAs were then conducted, one with each of the emergent perceptional components as the dependent variable and the meadow variables (species diversity, colour diversity and flowering abundance) and demographic variables (age, gender, ethnicity and whether a landscape/horticultural/environmental professional) as independent, to identify significant drivers of perceptions. In the case of variables with multiple categories, post hoc multiple comparisons using the Sidak correction distinguished significant differences between groups or categories. A further ANOVA was carried out to examine the interaction between 'Phase' (i.e., July, August or September) and colour diversity.

3.2. Invertebrate response to the meadows

To assess whether the same three variables (plant species diversity, flower colour diversity, or flower abundance) were important for the abundance and diversity of invertebrates, two measures of visual invertebrate biodiversity were calculated. The first was the abundance of a subset of five groups of surveyed invertebrates which would be clearly visible and perceptibly different from each other to a non-specialist casual observer: i) butterflies and moths, ii) true flies, iii) hoverflies), iv) bumblebees, v) honeybees and small bees. The second was a biodiversity index measuring visual invertebrate species diversity calculated as Simpson's index, (Magurran, 1988) for all the taxonomic groups recorded during the visual surveys. This was calculated for each plot at each phase of the visual invertebrate survey. In this case, diversity was calculated at the level of the taxonomic groups identified during the original non-specialist surveys. Here, this measure will be referred to as 'species' diversity, as the taxonomic level corresponds to the wording of the public survey question "How many species of native UK insects (flies, butterflies, bees) do you think this planting will support?" Table 2. ANOVA was used to analyse the effects of floral species diversity, colour diversity and flowering abundance on visual invertebrate biodiversity measures (perceived invertebrate abundance and overall visual invertebrate richness) as dependent variables and floral species diversity, colour diversity and flowering abundance as the independent variables. Actual invertebrate abundance (from the sweep samples) for the six groups described above was analysed in the same way, again with plant species diversity, colour diversity and flowering abundance as the independent variables. Correlations were then carried out between visual and comparable sweep sample invertebrate biodiversity measures for phase 2 of the experiment (August), when the latter were taken, to assess the extent to which actual invertebrate occurrence was related to that which could be seen by an observer. Finally, additional analyses of the observable hoverfly data were conducted to better understand a discrepancy between results for actual and observable invertebrate data. These included an ANOVA with observable hoverflies as dependent and phase as independent to identify differences in hoverfly abundance by phase, and a further ANOVA focusing on hoverfly abundance in relation to the interaction of colour diversity and phase.

3.3. Correlations between participants' perceived biodiversity measures and visual and actual plant and invertebrate biodiversity measures

To address the question, 'How well can members of the public observe and recognise plant and invertebrate biodiversity?' correlation was used to test the relationship between key measures of both. First, focusing on plant diversity, we examined the relationship between species diversity (high or low), and the response to the questionnaire item 'How many different plant species do you think there are here?'. We then looked at the relationship between forb colour diversity (high or low), and the same questionnaire item, to identify whether colour diversity was a stronger correlate of perceived species diversity than actual species diversity. For invertebrate biodiversity, we tested relationships between the Simpson's index (for visually sampled invertebrates) for each plot over all three phases of data collection and the items 'the planting along this walk appears good for butterflies, bees and other insects', and 'How many species of native UK insects (flies, butterflies, bees) do you think this planting will support?'. Correlations were then also carried out between the Simpson's score based on sweep samples and the same two questionnaire items (August 2015 data only).

4. Results

4.1. Public response to the meadows

The demographic profile of participants (n = 149) completing on-site questionnaires in July (n = 38), August (n = 67) and September (n = 44) is shown in Table 3. The gender balance was relatively even, but the sample was skewed towards the older age groups. Following the demographics of the local population, most of the survey participants were white British/Irish, but there was some ethnic diversity. Many participants neglected to complete the question about involvement in landscape/horticulture/environmental professions, but among those who did, these professions were well represented. Some participants made a planned visit to the site in response to the on-site signage informing the public of meadows 'opening days'.

Table 3
Questionnaire participants' (n = 149) demographic profile [*](valid %).

Gender (missing values = 11 respondents)	
M	63 (45.6%)
F	75 (54.4%)
Age (missing values = 10 respondents)	
18–24	10 (7.2%)
25–34	18 (12.9%)
35–44	23 (16.5%)
45–54	27 (19.4%)
55–64	22 (15.8%)
65 +	39 (28.1%)
Ethnicity (missing values = 12 respondents)	
White British/Irish	94 (68.6%)
White (other)	15 (10.9%)
Mixed white/black Caribbean	2 (1.5%)
Mixed white/Asian	1 (0.7%)
Mixed other	1 (0.7%)
Asian Indian	4 (2.9%)
Asian Pakistani	12 (8.8%)
Asian Bangladeshi	1 (0.7%)
Asian Chinese	1 (0.7%)
Black Caribbean	4 (2.9%)
Black other	2 (1.5%)
Landscape/horticulture/environmental professional? (Missing values = 62 respondents)	
Yes	21 (24.1%)
No	66 (75.7%)

* Valid percentages given due to missing values.

Table 4
Sorted pattern matrix for the two key dimensions of participants' perceptions (n = 149) emerging from principal components analysis with a varimax rotation. Item loading values > 0.3 are shown. Values > 0.5 are in bold.

Questionnaire item (Individual attitudinal statements & questions)	Components	
	Perceived aesthetic effect (Colour, attractiveness & diversity)	Perceived care & Restorative effect
The planting on this walk is colourful	**0.79**	
How many different plant species do you think there are here?	**0.76**	
The combination of colours is attractive in this planting	**0.76**	
The planting along this walk is attractive	**0.66**	
The planting along this walk is interesting	**0.63**	
How many species of native UK insects (flies, butterflies, bees) do you think this planting will support?	**0.53**	
How many native UK plant species do you think are in this planting?	0.45	
How structurally complex would you describe this planting?	0.43	0.35
The planting along this walk appears good for butterflies, bees and other insects	0.41	
The planting on this walk looks tidy		**0.75**
The planting on this walk looks cared for		**0.68**
The planting on this walk looks designed		**0.58**
This walk reveals a special unique place		**0.56**
I feel relaxed on this walk		**0.56**
I feel comfortable along this walk		**0.55**
This walk allows me to escape from more mundane routines and work		**0.50**
The planting on this walk looks natural	0.43	0.45
Variance explained %	31.15	10.17

Two components were extracted from the PCA of questionnaire items relating to research questions 1 and 2, together accounting for 41.3% variability in our participants' responses Table 4). These were interpretable as: colour, attractiveness, and biodiversity (31.2% variance) and care and restorative effect (10.2% variance). Individual questionnaire items loading onto specific components are shown Table 4.

i) What factors affected public aesthetic response?

Meadow flower colour diversity had a significant effect on participants' aesthetic perceptions of the planting Table 5). Meadows of high flower colour diversity were perceived as significantly more colourful, attractive and more biodiverse than those of low colour diversity. Meadow species diversity had no significant effect on aesthetic perception, yet attitudinal statements relating to perceived plant and invertebrate diversity loaded onto the same component (aesthetic effect) as 'attractiveness' Table 4. Flowering abundance had no significant effect. Whilst differences in colour diversity between treatments were maintained across the course of the experiment, because the species in flower changed, the exact nature of that difference was not constant. It is interesting, therefore, to look at whether the responses to colour treatments change across the three phases of the experiment. Results indicated a significant interaction effect of colour diversity and phase (see Fig. 2). The greatest difference in perception of aesthetic effect between high and low colour diversity meadows was in phase 1 (July), with the least in phase 3 (September). The highest scores for aesthetic effect were achieved in high flower colour diversity meadows in July, after which (in August and September), perceived aesthetic effect of high colour diversity plots declined. In contrast, the low colour diversity plots were most attractive in September, and least so in August. Being a landscape/horticultural/environmental professional also had a significant effect on aesthetic response Table 5. Professionals perceived the meadows to be significantly less colourful, attractive, and biodiverse than did other members of the public.

Table 5
Results of ANOVA with perceptional principal components as dependent and meadow and demographic variables as independent variables. Significant values are in bold. Marginal mean *(MM)* scores for significant variables are shown in bold.

	Perceptional principal components						
	Perceived aesthetic effect (colour, attractiveness & perceived biodiversity)				Perceived care & restorative effect		
	F	P-value	df	MM	F	P-value	df
Species diversity	1.22	0.27	1,55				
Colour diversity	**12.41**	**0.001**	**1,55**	**High 2.98 Low 2.21**	0	0.98	1,55
Flowering abundance	0.61	0.44	1,55		0.21	0.65	1,55
Age	0.85	0.52	5,55		0.37	0.87	5,55
Gender	0.31	0.58	1,55		1.75	0.19	1,55
[*]Ethnicity	1.4	0.23	6,55		**2.57**	**0.03**	**6,55**
Landscape/horticulture/environmental professional?	**6.59**	**0.01**	**1,55**	**Pro 2.23 Non-pro 2.98**	0.41	0.53	1,55

* Ethnicity sample sizes are too small for further interpretation.

ii) What factors affected restorative effect?

No meadow variables were associated with participants' perceptions of care and restorative effect Table 5. One demographic variable, *ethnicity,* was significant. However, the low numbers of participants from some ethnic groups limits any further interpretation of the robustness of this effect.

4.2. Invertebrate response to the meadows

Meadow flower colour diversity was significantly associated with the observable abundance of true flies, bumblebees and hoverflies Table 6). Meadow plots with high flower colour diversity were associated with significantly higher abundances of observable bumblebees than those with a low colour diversity, yet with a significantly lower abundance of observable flies and hoverflies. Analysis of actual invertebrate biodiversity from sweep samples taken during August

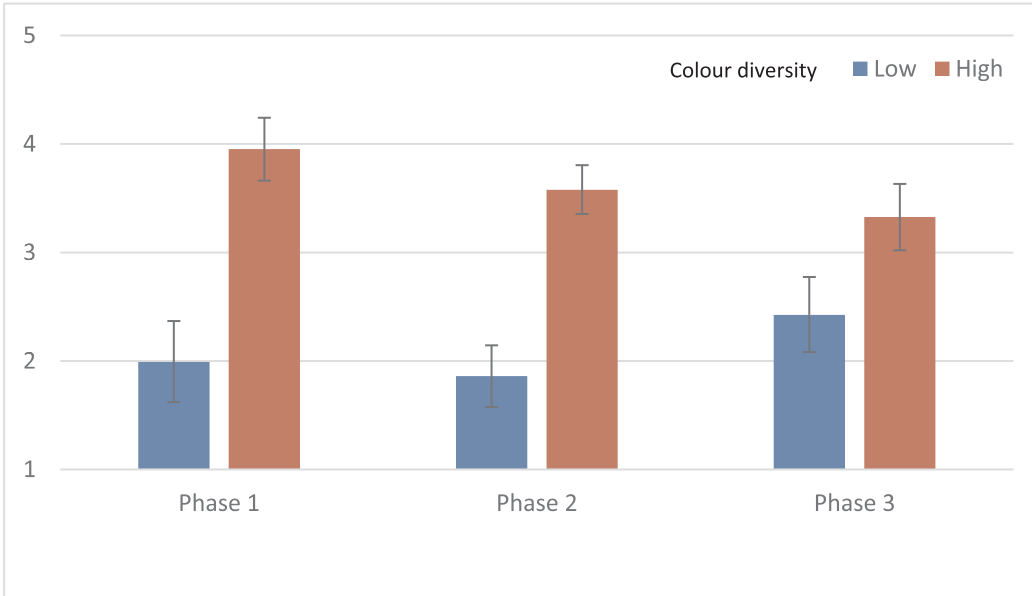

Fig. 2. Mean aesthetic effect (Colour, attractiveness & perceived biodiversity) by phase and colour diversity (Two-way ANOVA – interaction F = 8.96, d.f. = 5,112, P < 0.001). The greatest difference in perception of aesthetic effect between high and low colour diversity meadows was in phase 1 (July), with the least in phase 3 (September). The highest scores for aesthetic effect were achieved in high flower colour diversity meadows in July. In contrast, the low colour diversity plots were most attractive in September, and least so in August.

indicates a more complex pattern. Floral colour diversity had a significant effect on the abundance of hoverflies, true bugs and thrips, but no significant effect on the abundance of other invertebrate groups Table 7). In this case plots with a high flower colour diversity were associated with a significantly higher abundance of hoverflies than low diversity plots Table 7 but a significantly lower abundance of true bugs and thrips. For hoverflies at least, the pattern is less contradictory than it might seem. In August, when the sweep sampling of actual invertebrates was done numbers of observable hoverflies in high colour and low colour diversity plots were indistinguishable (high colour mean = 19.6, s.e. = 1.9, low colour mean = 19.3, s.e. = 2.6). However, observable hoverflies were least abundant overall in August (August mean = 19.5, s.e. = 1.6, July mean = 33.3, s.e. = 1.8, September mean = 28.9, s.e. = 2.2) and in both July and September there were slightly higher numbers of observable hoverflies in low colour diversity than high colour diversity plots (July: high colour mean = 30.4, s.e. = 2.6, low colour mean = 36.2, s.e. = 2.5 and September high colour mean = 27.4, s.e. = 2.4, low colour mean = 30.3, s.e. = 3.7).

Plant species diversity had no significant effect on any visual invertebrate biodiversity measure, but in the case of actual invertebrate biodiversity derived from the sweep samples, the abundance of true flies, true bugs and thrips, was significantly higher in the low species diversity plots Table 7. Actual invertebrate biodiversity was significantly correlated with visually observable invertebrate diversity only for the true flies (r = 0.61, d.f. = 23, *P* = 0.002).

4.3. Comparing participants' perceived biodiversity measures and actual plant and invertebrate biodiversity

i) Perceived and actual plant species diversity

There were significant correlations between perceived plant species diversity and actual meadow species diversity, (r = 0.27, d.f. = 139, *P* = 0.001) and between perceived plant species diversity and flower colour diversity (r = 0.39, d.f. = 139, *P* < 0.001). The latter was the stronger of the two relationships.

Table 6
Results of ANOVA for visual invertebrate biodiversity measures (observable invertebrate abundance and overall visual invertebrate diversity (Simpson's Index) as dependent and i) plant species diversity ii) colour diversity iii) flowering abundance as independent (df = 1, 20 in all cases). Significant values are in bold. Mean abundance scores for significant values are shown (high (H) and low (L) colour diversity).

Meadow variables	Visual Invertebrate biodiversity measures														
	Observable Invertebrate abundance													Overall visual invertebrate species diversity (Simpson's Index)	
	Observable Butterflies & Moths		Observable True Flies			Observable Hoverflies			Observable Bumblebees			Observable Honeybees & small bees			
	F	P-value	F	P-value	Mean	F	P-value	Mean	F	P-value	Mean	F	P-value	F	P-value
Species diversity	0.56	0.46	2.25	0.15	**(H) 40.71 (L) 79.13**	3.42	0.08	**(H) 75.16 (L) 88.09**	2.36	0.14		3.36	0.82	0.18	0.68
Colour diversity	1.45	0.24	**14.19**	**0.001**		**6.33**	**0.02**		**17.44**	**< 0.001**	**(H) 13.88 (L) 2.20**	1.19	0.29	2.17	0.16
Flowering abundance	0.24	0.63	1.51	0.75		3.70	0.07		0.10	0.76		0.76	0.40	0.09	0.77

Table 7
Results for ANOVA for actual invertebrate abundance (df = 1, 20 in all cases). Mean scores for significant values are shown: (High diversity (H), Low diversity (L)) Significant values are in bold.

Meadow variables	Actual Invertebrate biodiversity measures														
	Hoverflies			True flies			Parasitic wasps		Total bees		Butterflies and moths		Ladybirds		
	F	P-value	Mean	F	P-value	Mean	F	P-value	F	P-value	F	P-value	F	P-value
Species diversity	0.17	0.68		**6.71**	**0.02**	**(H) 83.94 (L) 173.15**	2.57	0.13	0.01	0.92	0.16	0.70	0.99	0.33
Colour diversity	**5.50**	**0.03**	**(H) 6.10 (L) 3.74**	3.77	0.07		2.92	0.10	0.25	0.62	0.05	0.83	3.49	0.08
Flowering abundance	0.71	0.41		3.36	0.08		**5.13**	**0.04**	3.06	0.10	0.88	0.36	0.16	0.69
	Other beetles			True bugs			Spiders		Thrips					
	F	P-value		F	P-value	Mean	F	P-value	F	P-value	Mean			
Species diversity	3.97	0.06		**21.54**	**< 0.001**	**(H) 7.56 (L) 48.44**	3.24	0.09	**32.954**	**< 0.001**	**(H) 19.16 (L) 104.75**			
Colour diversity	0.11	0.75		**13.51**	**0.001**	**(H) 12.91 (L) 43.10**	1.22	0.28	**7.69**	**0.012**	**(H) 42.68 (L) 81.24**			
Flowering abundance	0.02	0.90		**9.24**	**0.006**		1.51	0.23	1.20	0.29				

ii) Perceived and actual invertebrate richness

There was no significant correlation between either of the perceived invertebrate biodiversity measures (‘perceived value of the planting for butterflies, bees and other insects’ and ‘perceived number of species of native UK insects planting will support’) and overall visual or actual (sweep sample) invertebrate diversity as summarised by the visual and actual (sweep sample) Simpson’s indices.

5. Discussion

5.1. Public response to the meadows

i) Aesthetic response

We found that meadows with a higher flower colour diversity prompted a more positive aesthetic response, but plant species diversity was not significant in explaining aesthetic preference. This pattern was consistent across all demographic groups except in the case of landscape/environmental professionals versus non-professionals, with non-professionals recording higher aesthetic scores than professionals. Our findings in relation to flower colour and species diversity parallel those of Graves et al. (2017) who identified an increase in aesthetic preference with meadow flower colour diversity, and that aesthetic preference was unrelated to species diversity. Our work focused on public reaction to annual meadows in a UK urban park setting, whereas Graves et al. (2017) considered reactions to Appalachian mountain forest wildflower meadows. The correspondence of the results suggests the effects may have some transferability across cultures and geographical contexts. Focusing specifically on the public response to meadows in general in different cultural contexts, a UK study demonstrated that meadows were generally preferred to herbaceous borders and formal bedding plants (Southon et al., 2017) whereas in a later Chinese study (Yarong & Tao, 2017) urban meadows received the lowest satisfaction rating compared to lawns, monocultures, and flowerbeds. Other research on land manager perceptions of urban meadow introduction related to that by Southon et al. (2017) indicated that in the UK people are increasingly accepting of a messier urban aesthetic. Interviews with land managers indicated that this was related to heightened public awareness of the value of urban meadows to pollinators as well as the perception that meadows may offer a cost-effective method of managing grasslands than intensive mowing (Hoyle et al., 2017). These findings also acknowledged the perceived value of an ‘orderly frame’ to the ‘messy ecosystem’ as evidenced by earlier work (Nassauer, 1995).

That landscape professionals perceived the meadows to be significantly less colourful, attractive, and biodiverse than did other members of the public Table 5 is consistent with findings from the recent Chinese study described above (Yarong & Tao, 2017), again suggesting some wider cultural and geographical applicability. In other studies, professionals (Ozguner, Kendle, & Bisgrove, 2007) or students (Zheng, Zhang, & Chen, 2011) in fields such as conservation and environmental science have been shown to prefer more naturalistic planting styles to tidier, ordered planting, or to find these more restorative (Hoyle et al., 2017a) yet our findings in relation to the annual meadows show that perceived *care and restorative effect* were unrelated to being a landscape professional.

The scores for aesthetic effect varied through the three phases of our study. The highest scores for *aesthetic effect* were recorded in high flower colour diversity meadows in July when there was also the greatest difference in scores for *aesthetic effect* between the high and low colour diversity plots. This is likely to reflect the earlier flowering of some species present in these plots, for example, *Eschscholtzia californica* (Californian poppy), *Papaver rhoeas* (shirley poppy) and *Centaurea cyanus* (cornflower), which added to the overall colour diversity Table 1. In September, these species had ceased flowering and the perceived aesthetic effect of high flower colour diversity plots was reduced. The contrasting response to the low flower colour diversity plots, considered most attractive in September, and least so in August, is probably due to the later flowering of the *Coreopsis tinctoria* (plains coreopsis ‘tall’). This was not in flower in July, but in full flower in September.

Attitudinal statements relating to perceived plant and invertebrate species diversity also loaded onto the component ‘aesthetic effect’, which measured participants’ perceptions of colourfulness and attractiveness. This indicates a strong correlation between perceived colourfulness and attractiveness and perceived number of plant species present. However, as stated, actual plant species diversity had no significant effect on perceived aesthetic effect. This indicates that participants used meadow colour diversity rather than actual plant species diversity as a visual cue to the number of plant species they thought were present.

ii) Restorative effect

We considered the relative restorativeness of varying ‘natural’ settings, (i.e. meadows of varying colour diversity, species diversity and flowering abundance), applying the same direct rating approach to measure restorative effect as Hoyle et al. (2017a, 2017b). Han (2003) also considered the relative restorativeness of different natural environments, but at the macroscale, using colour slides to simulate the six major terrestrial biomes: tropical, coniferous and deciduous forests and grassland, tundra and desert environments. The majority of research measuring the relative restorativeness of different environments has focused on comparing urban (built) and natural environments (e.g. Herzog et al. 2003; Laumann, Garling, & Stormark, 2001) or those comprising mixed built and natural scenes (Tenngart Ivarsson, & Hagerhall, 2008). Herzog et al. (2003) also used a direct rating scale, focusing on assessing the restorative qualities of contrasting urban and field/forest natural areas, finding the latter more restorative. Direct ratings were higher for natural than urban settings on all four components: being away, extent, fascination and compatibility. In contrast, Tenngart Ivarsson and Hagerhall (2008) applied a more extensive 'Perceived Restorative Scale' (PRS) to assess the perceived restorativeness of two Swedish gardens comprising 'mixed built and natural scenes'. Their findings indicated differences in restorativeness between specific elements of the same broad scene type, thereby highlighting the shortcomings of applying this scale to such a broad heterogeneous area.

We found that attitudinal statements relating to perceived care loaded onto the same factor as those relating to restorative effect, suggesting that our participants associated 'cared for' meadows with self-reported restorative effect. This might be explained with reference to Nassauer's (1995) observation that people respond positively to visual 'cues to care' in the landscape such as trimmed edges and colourful flowers, indicating human stewardship. Nassauer (1995) suggested an increased acceptance of 'messy ecosystems' if they were contextualised within an 'orderly frame'. In the case of our meadows, each treatment occupied a rectangular plot as described in the methods and was framed by a mown grassy path.

Perceived care and restorative effect were, however unrelated to meadow flower colour diversity, species diversity, or flower abundance. This supports findings (Hoyle et al. 2017a) indicating that whilst flowering and colour are stimulating, resulting in an aesthetic 'wow factor', they are not the main drivers of restorative effect, with people finding green planting more calming and restorative. While one of the variables included to control for demographic effects (ethnicity) was significant, and various studies have suggested there may be important cultural and ethnic influences on preferences for different levels of management or tidiness in green spaces (Buijs, Elands, & Langers, 2009; Jay & Schraml, 2009; Kloek, Schouten, & Arts, 2010), the small sample sizes of most of the ethnic groups in this study precluded useful interpretation of these effects here. However, it does suggest that specific exploration of cultural influences on these perceptions of green space management may be a useful issue for further investigation.

5.2. Invertebrate response to the meadows

The significant association between high colour diversity plots and observable bumblebee abundance is consistent with evidence that pollinators select on perceived flower colour (Campbell et al. 2012), although this colour perception may be different to that of humans. Colour is one of several floral traits including scent and the width of flower tubes which affect pollinator use of flowers (Hirota et al., 2012). Pollinator selection of flowers according to colour occurs for a variety of reasons (Campbell et al., 2012), including the actual ability to distinguish colours, innate preference (Raine & Chitka, 2007), and learnt association with the rewards associated with other flower traits (Melendez-Ackerman et al., 1997; Menzel, 1979). Colour is likely to be primarily an indicator of resource availability in the flower, as insect flower visitation is driven mainly by resource use, notably pollen and nectar collection (Goulson & Osborne, 2009; Haslett, 1989; Kim et al., 2011). Most bee species have trichromatic colour vision resulting in excellent colour discrimination (Chittka & Wells, 2004; Dyer & Neumeyer, 2005; Kevan & Backhaus, 1998; Vasas, Hanley, Kevan, & Chittka, 2017). Pollinators such as generalist bumblebees tend to pollinate flowers with weak flower scent but strong flower colours (Ando, Nomura, Tsukahara, Watanabe, & Kokubun, 2001) and there is good evidence that flies use colour cues for flower visitation (Lunau, 2014). In the case of the sweep surveys, the presence of significantly higher numbers of hoverflies in the high colour diversity compared to low colour diversity plots in August is consistent with the hypothesis (Campbell et al., 2012) that flower colour is an important plant selection criterion for some insects. There were more strong flower colours on display in the high colour diversity plots in August, when the blue *Centaurea cyanus* (cornflower) and red *Papaver rhoeas* (shirley poppy) were still in flower. The high numbers of observable hoverflies in July may be attributable to the early flowering orange *Eschscholtzia californica* (Californian poppy) as well as *Centaurea cyanus* (cornflower). In September the high abundance of observable hoverflies, particularly in the low colour diversity plots, could to be related to the later flowering yellow *Coreopsis tinctoria* (plains coreopsis 'tall'). This species was present in all eight treatments, particularly the low colour diversity ones, where the contribution to the species mix was 30% or above in two cases Table 1. By September few other species were in flower. However, caution is necessary in attributing effects to colour. Garbuzov and Ratnieks (2014) focused on insect visits to 32 popular native and non-native garden plants over two extended summer flowering seasons and found that colour did not appear to be an important factor driving the attractiveness of plants to insects.

In our study, the significantly lower number of true bugs and thrips in the high colour diversity plots is interesting, though the reason for it is not clear. One speculative possibility is that it might be an indirect effect reflecting the impact of invertebrate, or other predators attracted to the high colour diversity plots by increased pollinator abundance.

The higher numbers of true flies, true bugs and thrips in plots of low, compared with high plant species diversity is also an interesting pattern, whose explanation is, again, not obvious. It could be related to the abundant floral resources being provided by a limited number of types of flower which happen to be good resources for species in those taxa (Salisbury et al., 2015). It could also be related to the habitat structure. A high percentage of *Coreopsis tinctoria,* (plains coreopsis 'tall') was present in the low species diversity plots. The relatively tall stems and high stem density of these plots might have had resource or habitat value for thrips, bugs and true flies which were not visible during the visual surveys (Dennis, Young, & Gordon, 1998; Morris, 2000; Valtonen, Saarinen, & Jantunen, 2006). There is also evidence that thrips prefer to feed on tender plant parts such flowers and new leaves (Kirk, 1995).

5.3. Do people observe and recognise plant and invertebrate biodiversity?

One important question when considering the management of GI is the extent to which improvements in actual biodiversity can be achieved which are evident and observed by people; bringing any wellbeing benefits that may accrue from perceptions of higher biodiversity (Fuller et al., 2007). In the experimental meadows here there was limited correspondence between the invertebrate diversity seen by an observer and that recorded from more systematic sampling, with the exception of one taxon, flies. These are very active, particularly in frequent flight, and readily recognised, which may contribute to this, though similar arguments might equally be applied to groups such as hoverflies or butterflies. In the case of the latter, sampling may be a contributory factor, as the sweep net sampling employed is not particularly effective for butterflies. What these results do suggest is that people's perception of invertebrate biodiversity from what is most readily observed is likely to be very taxon-dependent.

Earlier evidence that our participants used colour diversity as a cue to assessing plant species diversity is reinforced by the stronger correlation between colour diversity and the number of plants species participants perceived to be present than that between species diversity and the same variable. This suggests that our participants had limited ability to assess plant species diversity accurately, yet they were able to recognise the difference between two broad levels of plant species diversity. The lack of any significant relationship between either of the two perceived invertebrate measures and both visual and actual (sweep sample) invertebrate diversity (Simpson's Index) provides similar evidence. This concurs with findings from other research highlighting the inability of the public to identify biodiversity at the species level (Dallimer et al., 2012; Fischer et al., 2011; Fuller et al., 2007). In the case of our research it is perhaps more surprising, given that many of our participants were from environmental/horticultural/landscape professions.

6. Conclusions and implications for practice and further research

Our results highlight the role of meadow flower colour diversity as an important factor in human aesthetic response, and the abundance in plots of specific pollinators, namely bumblebees and hoverflies. They show that plant species diversity did not have a significant effect on aesthetic response and that people may use flower colour diversity as a cue to estimate how many plant species they think are present. This, together with the lack of correspondence between perceived and visual and actual invertebrate measures indicates that the public had very limited awareness or understanding of the true plant and invertebrate biodiversity value of the sown meadow plots. Plant species diversity had some effect on invertebrate response, with higher abundances of some groups such as thrips in low species diversity meadows. Participants' self-reported restorative effect was unrelated to any meadow variable.

Our findings indicate that if the priority for sown meadows is to maximise human aesthetic enjoyment and the abundance and diversity of observable invertebrates, particularly pollinators, GI managers should be prioritising high flower colour diversity mixes, because both people and visible invertebrates respond most positively to these. If increasing plant diversity is a goal, also considering flower colour diversity would be a useful addition. The inclusion of late-flowering non-native species such as *Coreopsis tinctoria* (plains coreopsis 'tall') can extend the flowering season into September, thereby extending the time frame of attractiveness to people and availability of resources for invertebrates beyond that afforded by native UK species. Importantly, landscape professionals making decisions about the introduction of annual meadows in urban areas should also reflect on the divergence of their own perspective on the aesthetic qualities of annual meadows from that of the wider population, who are likely to be more positive about their introduction.

Future research is needed to focus on both public and invertebrate response to specific flower colours and combinations. A more detailed focus on the role of local ethnicity in perception of different approaches to urban GI management practice and its outcomes would also be desirable.

Acknowledgements

This work is part of the project *Fragments, functions and flows – the scaling of biodiversity and ecosystem services in urban ecosystems* funded by grant NE/J015369/1 from the Biodiversity and Ecosystem Service Sustainability (BESS) programme. BESS is a six-year programme (2011 – 2017) funded by the UK Natural Environment Research Council (NERC) and the Biotechnology and Biological Research Council (BBSRC) as part of the UK's Living with Environmental Change (LWEC) programme. This work presents the outcomes of independent research funded by the Natural Environment Research Council through the Biodiversity and Ecosystem Service Sustainability (BESS) programme. The views expressed are those of the authors and not necessarily those of the BESS Directorate or NERC.

We are grateful to Luton Borough Council Parks Service for their collaboration and support of this project and to the specialist meadow company, Pictorial Meadows, who generously donated the annual seed to support this research.

References

Akbar, K. F., Hale, W. H. G., & Headley, A. D. (2003). Assessment of scenic beauty of the roadside vegetation in northern England. *Landscape and Urban Planning, 63*, 139–144. https://doi.org/10.1016/S0169-2046(02), 00185-8.

Ando, T., Nomura, M., Tsukahara, J., Watanabe, H., Kokubun, H., et al. (2001). Reproductive isolation in a native population of Petunia sensu Jussieu (Solanaceae). *Annals of Botany, 88*, 403–413.

Baldock, K. C. R., Goddard, M. A., Hicks, D. M., Kunin, W. E., Mitschunas, N., Osgathorpe, L. M., et al. (2015). Where is the UK's pollinator biodiversity? The importance of urban areas for flower-visiting insects. *Proceedings of the Royal Society B, 282*, 20142849.

Baldock, K., Memmott, J., Ruiz-Guajardo, J.-C., Roze, D., & Stone, G. (2011). Daily temporal structure in African savanna flower visitation networks and consequences for network sampling. *Ecology, 92*(3), 687–698.

Blackmore, L. M., & Goulson, D. (2014). Evaluating the effectiveness of wildflower seed mixes for boosting floral diversity and bumblebee and hoverfly abundance in urban areas. *Insect Conservation and Diversity, 7*(5), 480–484.

Buijs, A. E., Elands, B. H. M., & Langers, F. (2009). No wilderness for immigrants: Cultural differences in images of nature and landscape preferences. *Landscape and Urban Planning, 91*, 113–123.

Buri, P., Humbert, J., & Arlettaz, R. (2014). Promoting pollinating insects in intensive agricultural matrices: Field-scale experimental manipulation of hay-meadow mowing regimes and its effects on bees. *PLoS One, 9*(1), https://doi.org/10.1371/journal.pone.0085635.

Campbell, D. R., Bischoff, M., Lord, J. M., & Robertson, A. W. (2012). Where have all the blue flowers gone: Pollinator responses and selection on flower colour in New Zealand Wahlenbergia albomarginata. *Journal of Evolutionary Biology, 25*, 352–364. https://doi.org/10.1111/j.1420-9101.2011.02430.

Carrus, G., Scopelliti, M., Lafortezza, R., Colangelo, G., Ferrini, F., Salbitano, F., et al. (2015). Go greener, feel better? The positive effects of biodiversity on the well-being of individuals visiting urban and peri-urban green areas. *Landscape and Urban Planning, 134*, 221–228. https://doi.org/10.1016/j.landurbplan.2014.10.022.

Chamberlain, S., Vazquez, D. P., Carvalheiro, L., Elle, E., & Vamosi, J. C. (2014). Phylogenetic tree shape and the structure of mutualistic networks. *Journal of Ecology, 102*, 1234–1243.

Chittka, L., & Wells, H. (2004). Color vision in bees: Mechanisms, ecology and evolution. In F. Prete (Ed.). *Complex worlds from simpler nervous systems* (pp. 165–191). Boston: MIT.

Clark, N. E., Lovell, R., Wheeler, B. W., Higgins, S. L., Depledge, M. H., & Norris, K. (2014). Biodiversity, cultural pathways, and human health: A framework. *Trends in Ecology and Evolution, 29*(4), 198–204. https://doi.org/10.1016/j.tree.2014.01.009.

Dallimer, M., Irvine, K. N., Skinner, A. M. J., Davies, Z. G., Rouquette, J. R., Maltby, L. L., et al. (2012). Biodiversity and the feel – good factor: Understanding associations between self – reported human well – being and species richness. *BioScience, 62*(1), 47–55. https://doi.org/10.1525/bio.2011.61.10.10.

Dennis, P., Young, M. R., & Gordon, I. J. (1998). Distribution and abundance of small insects and arachnids in relation to structural heterogeneity of grazed, indigenous grasslands. *Ecological Entomology, 23*, 253–264.

Dyer, A. G., & Neumeyer, C. (2005). Simultaneous and successive colour discrimination in the honeybee *(Apis mellifera)*. *Journal of Comparative Physiology A, 191*, 547–557.

EU Biodiversity Strategy to 2020 http://ec.europa.eu/environment/nature/biodiversity/strategy/index_en.htm (Accessed 4th November 2016).

European Commission Research and Innovation Policy, (2016) https://ec.europa.eu/research/environment/index.cfm?pg=nbs (Accessed 17th October 2016).

Fischer, A., Bednar-Friedl, B., Langers, F., Dobrovodska, M., Geamana, N., Skogen, K., & Dumortier, M. (2011). Universal criteria for species conservation priorities? Findings from a survey of public views across Europe. *Biological Conservation, 114*(3), 998–1007. https://doi.org/10.1016/j.biocon.2010.12.004.

Forestry Commission, (2006) http://www.forestry.gov.uk/fr/urgc-7edjsm (Accessed 4th November 2016).

Frawley, B. J., & Best, L. B. (1991). Effects of mowing on breeding bird abundance and species composition in alfalfa fields. *Wildlife Society Bulletin, 19*(2), 135–142.

Fuller, R., Irvine, K., Devine-Wright, P., Warren, P., & Gaston, K. (2007). Psychological benefits of greenspace increase with biodiversity. *Biology Letters, 3*, 390–394. https://doi.org/10.1098/rsbl.2007.014910.

Garbuzov, M., Fensome, K. A., & Ratnieks, F. L. W. (2015). Public approval plus more wildlife: Twin benefits of reduced mowing of amenity grass in a suburban public park in Saltdean. *UK. Insect Conservation and Diversity, 8*(2), 107–119. https://doi.org/10.111/icad.12085.

Garbuzov, M., & Ratnieks, F. L. W. (2014). Quantifying variation among garden plants in attractiveness to bees and other flower-visiting insects. *Functional Ecology, 28*(2), 364–374.

Garratt, C. M., Minderman, J., & Whittingham, M. J. (2012). Should we stay or should we go now? What happens to small mammals when grass is mown, and the implications for birds of prey. *Annales Zoologici Fennici. 49*(1–2) Finnish Zoological and Botanical Publishing.

Glasgow & Clyde Valley Green Network Partnership, (2016). https://www.gcvgreennetwork.gov.uk/guide-to-the-gn/what-is-the-gn (accessed, 15th December 2017).

Goulson, D., & Osborne, J. L. (2009). Foraging range and the spatial distribution of

worker bumblebees. *Food exploitation by social insects, ecological, behavioral, and theoretical approaches* (pp. 97–111). Boca Raton FL: CRC Press.
Graves, R. A., Pearson, S. M., & Turner, M. G. (2017). Species richness alone does not predict cultural ecosystem service value. *PNAS, 114*(14), 3774–3779. https://doi.org/10.1073/pnas.1701370114.
Greater London Authority, (2015). Natural Capital: Investing in a Green Infrastructure for a future London. https://www.london.gov.uk/sites/default/files/gitaskforcereport.hyperlink.pdf (Accessed 15th December 2017).
Han (2003). A reliable and valid self-rating measure of the restorative quality of natural environments. *Landscape and Urban Planning, 64*, 209–232.
Hanley, N., & Barbier, E. (2009). *Pricing nature: Cost-benefit analysis and environmental policy.* Cheltenham: Edward Elgar.
Harmon-Threatt, A. N., & Hendrix, S. P. (2015). Prairie restorations and bees: The potential ability of seed mixes to foster native bee communities. *Basic and Applied Ecology, 16*, 64–72.
Hartig, T., Mitchell, R., de Vries, S., & Frumkin, H. (2014). Nature and health. *Annual Review of Public Health, 35*, 207–228.
Haslett, J. R. (1989). Interpreting patterns of resource utilization: Randomness and selectivity in pollen feeding by adult hoverflies. *Oecologia, 78*(4), 433–442.
Haviland-Jones, J., Hale, H., Wilson, P., & McGuire, T. R. (2005). An Environmental approach to positive emotion: Flowers. *Evolutionary Psychology, 3*, 104–132. https://doi.org/10.1177/147470490500300109.
Heard, M. S., Carvell, C., Carreck, N. L., Rothery, P., Osborne, J. L., & Bourke, A. F. G. (2007). Landscape context not patch size determines bumble-bee density on flower mixtures sown for agri-environment schemes. *Biology Letters, 3*, 638–641.
Herzog, T. R., Maguire, C. P., & Nebel, M. B. (2003). Assessing the restorative components of environments. *Journal of Environmental Psychology, 23*, 159–170.
Hirota, S. K., Nitta, K., Kim, Y., Kato, A., Kawakubo, N., Yasumoto, A. A., & Yahara, T. (2012). Relative role of flower color and scent on pollinator attraction: Experimental tests using F1 and F2 hybrids of daylily and nightlily. *PLoS One, 7*(6), e39010. https://doi.org/10.1371/journal.pone.0039010.
Hoyle, H., Hitchmough, J. D., & Jorgensen, A. (2017b). All about the 'wow factor'? The relationships between aesthetics, restorative effect and perceived biodiversity in designed urban planting. *Landscape and Urban Planning, 164*, 109–123. https://doi.org/10.1016/j.landurbplan.2017.03.011.
Hoyle, H. E., Hitchmough, J. D., & Jorgensen, A. (2017a). Attractive, climate-adapted and sustainable? Public perception of non-native planting in the designed urban landscape. *Landscape and Urban Planning, 164*, 49–63. https://doi.org/10.1016/j.landurbplan.2017.03.009.
Hoyle, H., Jorgensen, A., Warren, P., Dunnett, N., & Evans, K. (2017). "Not in their front yard" The opportunities and challenges of introducing perennial urban meadows: A local authority stakeholder perspective. *Urban Forestry & Urban Greening, 25*, 139–149. https://doi.org/10.1016/j.ufug.2017.05.009.
Hoyle, (2016) Improving urban grassland for people and wildlife. LWEC Living with Environmental Change Policy and Practice Note 32 http://www.nerc.ac.uk/research/partnerships/ride/lwec/ppn/ppn32/ (Accessed 22nd August 2017).
Irvine, K. N., Devine-Wright, P., Payne, S. R., Fuller, R. A., Painter, B., & Gaston, K. J. (2009). Greenspace, soundscape and urban sustainability: An interdisciplinary empirical study. *Local Environment, 14*, 155–172.
Ives, C. D., & Kendal, D. (2013). Values and attitudes of the urban public towards peri – Urban agricultural land. *Land Use Policy, 34*, 80–90. https://doi.org/10.1016/j.landusepol.2013.02.003.
Jay, M., & Schraml, U. (2009). Understanding the role of urban forests for migrants: Uses, perception and integrative potential. *Urban Forestry and Urban Greening, 8*, 283–294.
Kaplan, S. (1995). The restorative benefits of nature: Towards an integrative framework. *Journal of Environmental Psychology, 15*, 169–182. https://doi.org/10.1016/0272-4944(95), 90001-2.
Kazmierczak, A., Armitage, R., & James, P. (2010). Urban green spaces: Natural and accessible? The case of Greater Manchester, UK. In N. Muller, P. Werner, & J. Kelcey (Eds.). *Biodiversity and design* (pp. 383–405). Wiley Blackwell.
Kendal, D., Williams, K. J. H., & Williams, N. S. G. (2012). Plant traits link people's plant preferences to the composition of their gardens. *Landscape and Urban Planning, 105*, 34–42. https://doi.org/10.1016/j.landurbplan.2011.11.023.
Kevan, P. G., & Backhaus, W. G. (1998). Color vision: Ecology and evolution in making the best of the photic environment. In W. Backhaus, R. Kliegl, & J. Werner (Eds.). *Color vision: Perspectives from different disciplines* (pp. 163–183). Berlin: Walter de Gruyter.
Kim, W., Gilet, T., & Bush, J. W. (2011). Optimal concentrations in nectar feeding. *Proceedings of the National Academy of Sciences, 108*(40), 16618–16621.
Kirk, W. D. J. (1995). Feeding behavior and nutritional requirements. In B. L. Parker, M. Skinner, & T. Lewis (Eds.). *Thrips biology and management* (pp. 21–29). Plenum Press.
Kloek, M. E., Schouten, M. G. C., & Arts, B. (2010). Hedendaagse literatuur en natuurbeelden. Verkenning van natuurbeelden in literatur van autochtone schrijvers met een Marokkaanseachtergrond. *Landschap, 27*(1), 5–15.
Laumann, K., Garling, T., & Stormark, K. M. (2001). Rating scale measures of restorative components of environments. *Journal of Environmental Psychology. 23*, 125–134. https://doi.org/10.1006/jevp.2000.0179.
Lindemann-Matthies, P., & Bose, E. (2007). Species richness, structural diversity and species composition in meadows created by visitors of a botanical garden in Switzerland. *Landscape and Urban Planning, 79*, 298–307. https://doi.org/10.1016/j.landurbplan.2006.03.007.
Lindemann-Matthies, P., Junge, X., & Matthies, D. (2010). The influence of plant diversity on people's perception and aesthetic appreciation of grassland vegetation. *Biological Conservation, 143*, 195–202.
Lovell, R. (2016) Natural England Access to Evidence Information Note EIN018 Links between natural environments and mental health: evidence briefing. https://beyondgreenspace.files.wordpress.com/2016/07/ein018_edition_1.pdf [Accessed 30th November 2017].
Lunau, K. (2014). Visual ecology of flies with particular reference to colour vision and colour preferences. *Journal of Comparative Physiology A, 200*(6), 497–512.
Magurran, A. E. (1988). *Ecological diversity and its measurement.* London & Sydney: Croom Helm.
Melendez-Ackerman, E. J., Campbell, D. R., & Waser, N. M. (1997). Hummingbird behavior and mechanisms of selection on flower color in Ipomopsis. *Ecology, 78*, 2532–2541.
Menzel, R. (1979). Behavioural access to short-term memory in bees. *Nature, 281*, 368–369.
Morris, M. G. (2000). The effects of structure and its dynamics on the ecology and conservation of arthropods in British grasslands. *Biological Conservation, 95*, 129–142.
Nassauer, J. I. (1995). Messy ecosystems, orderly frames. *Landscape Journal, 14*, 161–170.
Ogunseitan, O. A. (2005). Topophilia and the quality of life. *Environmental Health Perspectives, 113*(14).
Ozdemiroglu, E. & Hails, R. (Eds.) (2016). Demystifying economic valuation, valuing nature paper VNP04.
Ozguner, H., Kendle, A. D., & Bisgrove, R. J. (2007). Attitudes of landscape professionals towards naturalistic versus formal urban landscapes in the UK. *Landscape and Urban Planning, 81*(1–2), 34–45. https://doi.org/10.1016/j.landurbplan.2006.10.002.
Pellmyr, O. (2002). Pollination by animals. In C. M. Herrera, & O. Pellmyr (Eds.). *Plant-animal interactions* (pp. 157–184). Malden: Blackwell.
Qiu, L., Lindberg, S., & Nielsen, A. B. (2013). Is biodiversity attractive? On-site perception of recreational and biodiversity values in urban greenspace. *Landscape and Urban Planning, 119*, 136–146. https://doi.org/10.1016/j.landurbplan.2013.07.007.
Raine, N. E., & Chittka, L. (2007). The adaptive significance of sensory bias in a foraging context: Floral colour preferences in the bumblebee Bombus terrestris. *PLoS One, 2*, e556.
Rudd, H., Vala, J., & Schaefer, V. (2002). Importance of backyard habitat in a comprehensive biodiversity conservation strategy: A connectivity analysis of urban green spaces. *Restoration Ecology, 10*(2), 368–375.
Salisbury, A., Armitage, J., Bostock, H., Perry, J., Tatchell, M., & Thompson, K. (2015). Enhancing gardens as habitats for flower-visiting aerial insects (pollinators): Should we plant native or exotic species? *Journal of Applied Ecology, 52*, 1156–1164. https://doi.org/10.1111/1365-2664.12499.
Southon, G. E., Jorgensen, A., Dunnett, N., Hoyle, H., & Evans, K. L. (2017). Biodiverse perennial meadows have aesthetic value and increase residents' perceptions of site quality in urban green-space. *Landscape and Urban Planning, 158*, 105–118. https://doi.org/10.1016/j.landurbplan.2016.08.003.
Strumse, E. (1996). Demographic differences in the visual preferences for agrarian landscapes in Western Norway. *Journal of Environmental Psychology, 116*, 17–31. https://doi.org/10.1006/jevp.1996.0002.
Tenngart Ivarsson, C., & Hagerhall, C. M. (2008). The perceived restorativeness of gardens – Assessing the restorativeness of a mixed built and natural scene type. *Urban Forestry & Urban Greening, 7*, 107–118. https://doi.org/10.1016/j.ufug.2008.01.001.
Todorova, A., Asakawa, S., & Aikoh, T. (2004). Preferences for and attitudes towards street flowers and trees in Sapporo, Japan. *Landscape and Urban Planning, 69*, 403–416. https://doi.org/10.1016/j.landurbplan.2003.11.001.
Valtonen, A., Saarinen, K., & Jantunen, J. (2006). Effect of different mowing regimes on butterflies and diurnal moths on road verges. *Animal Biodiversity and Conservation, 29*(2), 133–148.
Vandermeulen, V., Verspecht, A., Vermeire, B., Van Huylenbroeck, G., & Gellynck, X. (2011). The use of economic valuation to create public support for green infrastructure investments in urban areas. *Landscape and Urban Planning, 103*(2), 198–206.
Vasas, V., Hanley, D., Kevan, P. G., & Chittka, L. (2017). Multispectral images of flowers reveal the adaptive significance of using long-wavelength-sensitive receptors for edge detection in bees. *Journal of Comparative Physiology A, 203*, 301–311. https://doi.org/10.1007/s00359-017-1156-x.
Velarde, M. D., Fry, G., & Tveit, M. (2007). Health effects of viewing landscapes – Landscape types in environmental psychology. *Urban Forestry and Urban Greening, 6*(4), 199–212. https://doi.org/10.1016/j.ufug.2007.07.001.
Watkins, M. W. (2005). Determining parallel analysis criteria. *Journal of Modern Applied Statistical Methods, 5*(2), 344–346.
White, M. P., Alcock, I., Wheeler, B. W., & Depledge, M. H. (2013). Would you be happier living in a greener urban area? A fixed-effects analysis of panel data. *Psychological Science, 24*(6), 920–928. https://doi.org/10.1177/0956797612464659.
Williams, N. S. G., Lundholm, J., & MacIvor, J. S. (2014). Do green roofs help urban biodiversity conservation? *Journal of applied ecology, 51*(6), 1643–1649.
Winfree, R., Dushoff, J., Williams, N., & Kremen, C. (2014). Species abundance, not diet breadth, drives the persistence of the most linked pollinators as plant-pollinator networks disassemble. *American Naturalist, 183*, 600–611.
Yarong, J., & Tao, Y. (2017). Public perceptions and preferences for meadows in Beijing, China. *Urban Forestry and Urban Greening, 27*, 324–331. https://doi.org/10.1016/j.ufug.2017.07.004.
Zheng, B., Zhang, Y., & Chen, J. (2011). Preference to home landscape: Wildness or neatness? *Landscape and Urban Planning, 99*, 1–8. https://doi.org/10.1016/j.landurbplan.2010.08.006.